UUM 526
Optimization Techniques in Engineering
Spring 2017-2018

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Lecture Times and Office Hours

Time: Tuesdays 08:30-11:30
Place: Faculty of Aeronautics and Astronautics, Classroom D210
Prof. Ure Office Hours: By appointment

Course Objectives

- To provide students a solid understanding of fundamentals of optimization theory.
- To present core theorems and applications regarding most common optimization problems and algorithms.
- To provide students the mathematical and computational tools required to perform research at the MSc and PhD level.

Prerequisites

A solid knowledge of graduate level

- Linear Algebra
- Multivariable Calculus
- Scientific Programming

Important Note: It is strongly recommended that you take UUM 535 Engineering Mathematics before this course.

Lecture Topics

Introductory Lectures

- **Lecture 0:** Class Logistics
- **Lecture 1:** Introduction to Optimization
- **Lecture 2:** Mathematical Preliminaries
  - Proof Techniques

  - Linear Algebra
  - Geometry
  - Multivariable Calculus
- **Lecture 3:** Basics of Optimization
  - Condition for Local Minimizers

Part I: Unconstrained Optimization

- **Lecture 4:** One Dimensional Optimization
  - Golden Section Search
  - Fibonacci Search
  - Bisection Method
  - Newton's Method
  - Secant Method
- **Lecture 5:** Gradient Methods
  - The Method of Steepest Descent
  - Analysis of Gradient Methods
- **Lecture 6:** Netwon's Method
  - Newton's Method
  - Analysis of Newton's Method
  - Levenberg-Marquardt Modification
- **Lecture 7:** Conjugate Direction Methods
  - Conjugate Direction Algorithm
  - Conjugate Gradient Algorithm
- **Lecture 8:** Quasi-Newton Methods
  - Approximating the Inverse Hessian
  - Rank One Correction Formula
  - DPF Algorithm
  - BFGS Algorithm
- **Lecture 9:** Least Squares Problems
  - Least Squares Analysis
  - Recursive Least Squares Algorithm
  - Minimum Norm Problems
- **Lecture 10:** Neural Networks
  - Single Neuron Training
  - The Backpropagation Algorithm
- **Lecture 11:** Global Search Algorithms
  - Nelder-Mead Simplex Algorithm
  - Simulated Annealing
  - Particle Swarm Optimization
  - Genetic Algorithms

Part II: Linear Programming

- **Lecture 12:** Introduction To Linear Programming
  - Examples of Linear Programs
  - Standard Form
  - Basic Solution
  - Geometry of Linear Programming
- **Lecture 13:** Simplex Method
  - Row Operations
  - Canonical Augmented Matrix
  - Simplex Algorithm
  - Two Phase Simplex Method
- **Lecture 14:** Duality
  - Dual Linear Programs
  - Properties of Dual Problems
- **Lecture 15:** Integer Programming
  - Integer Programs
  - Unimodular Matrices
  - Cutting Plane Method

Part III: Constrained Nonlinear Programming

- **Lecture 16:** Problems with Equality Constraints
  - Tangent and Normal Spaces
  - Lagrange Condition
  - Second Order Conditions
- **Lecture 17:** Problems with Inequality Constraints
  - Karush-Kuhn-Tucker Conditions
  - Second Order Conditions
- **Lecture 18:** Convex Optimization Problems

  - Convex Functions
  - Convex Problems
  - Semidefinite Programming
- **Lecture 19:** Algorithms for Constrained Optimization
  - Projections
  - Projected Gradient Methods
  - Lagrangian Algorithm
  - Penalty Methods
- **Lecture 20:** Multiobjective Optimization
  - Pareto Solutions
  - Computing Pareto Front
  - From Multiobjective Optimization to Single Objective Optimization
  - Uncertain Linear Programs

Textbooks

- Main Textbook: *Chong, Edwin KP, and Stanislaw H. Zak. An Introduction to Optimization. Vol. 76. John Wiley and Sons, 2013.*
- Secondary Textbook: *Boyd, Stephen, and Lieven Vandenberghe. Convex Optimization. Cambridge university press, 2004.*
- Additional Textbook: *Arora, J.S., 2004. Introduction to Optimum Design, Elsevier Academic Press.*

Grading

- Problem Sets (30%)
- Take-Home Midterm (20%)
- Term Project (20%)
- Take-Home Final Exam (30%)

Grading Policies

- Cheating is strictly monitored and the penalty is -100 (minus hundred) points per assignment.
- Late assignments get -30 (minus thirty) points for each day after the deadline.
- No team work is allowed on problem sets and exams.
- Solutions typeset with LaTeXget +10 bonus points.
- Each problem set will also contain a bonus problem, which will earn the student +10 bonus points if solved correctly.

Classroom Policies

- No attendance is required.
- Coming late to the class is tolerated.
- Bringing computers to the class is welcome.
- Unregistered listeners are welcome.
- Interacting with the the instructor is strongly recommended.
- Extra problem solving sessions (date and place TBA) will be conducted by TA Ugur Akcal.